A resonant hollow MEMS device for multidimension analysis

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Publication date:
2018

Document Version
Peer reviewed version

A resonant hollow MEMS device for multi-dimension analysis

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Keywords: hollow MEMS, resonator, single cell, IR absorbtion

MOTIVATION

Resonant MEMS sensors enable precision measurements of a large range of sample properties with small sample sizes. However, the high responsivity and sensitivity often depends on operation in vacuum so minimize mechanical noise through dissipation. This limits the usability of the resonant MEMS principle when measuring liquids and bio-samples.

INTRODUCTION

The presented hollow MEMS sensor enables multi parameter analysis (density, viscosity, buoyant mass and IR absorption spectrometry) of picoliters of liquid sample. This facilitates advanced single cell measurements of relevance for drug development. The structures have been tailored to enable and maximize responsivity when performing measurements on single yeast cells, e.g. the buoyant mass and density of individual bacteria[1] or cells[2], [3], or viscosity[4] variations in the surrounding media. The sensors designed, fabricated and tested in this work, enable all these types of measurements and add the ability to perform IR absorption spectrometry.

FABRICATION

The fabrication process is based on the surface channel technology principle[5]. The optimized fabrication process (fig.1) can easily be tuned to fit the desired mass- or absorbed power responsivity, while still maintaining a fabrication yield close to 100%. Images of the finished sensor can be seen in fig. 2.

RESULTS AND DISCUSSION

The buoyant mass distribution of a population of yeast cells was measured by measuring the resonance frequency while the sample was flowing through the resonator. Phase Locked Loop (PLL) frequency tracking was performed with a Lock-In amplifier in combination with a laser-Doppler interferometer and a piezo electric crystal for transduction. The PLL bandwidth was set to 1kHz and the measured Q factor for the filled device was on the order of 4000. The frequency noise floor at this bandwidth is <4 ppm which translates to a minimum detectable buoyant mass of 2.75 pg (SNR=2). Results are consistent with expected values for single cells and expected frequency shifts from both theory and FE simulations.

OUTLOOK

After establishing that buoyant mass, density, viscosity and IR absorption measurements are possible with this device, future work will focus on exploiting the benefits of getting multiple signals at the same time, for example in the context of cell response to APIs.

REFERENCES

[1] Lewis, C.L., *et al.* Mass and Density Measurements of Live and Dead Gram-Negative and GramPositive Bacterial Populations. *Appl. Environ. Microbiol.* **80**, 3622–3631 (2014).
[2] Grover, W.H. *et al.* Measuring single-cell density. *Proc. Natl. Acad. Sci.* **108**, 10992–10996 (2011).
[3] Bryan, A.K. *et al.* Measuring single cell mass, volume, and density with dual suspended microchannel resonators. *Lab Chip* **14**, 569–76 (2014).
[4] Khan, M.F. *et al.* Online measurement of mass density and viscosity of pL fluid samples with suspended microchannel resonator. *Sensors Actuators B Chem.* **185**, 456–461 (2013).
[5] Dijkstra, M. et al. A versatile surface channel concept for microfluidic applications. *Micromechanics Microengineering* **17**, 1971–1977 (2007).

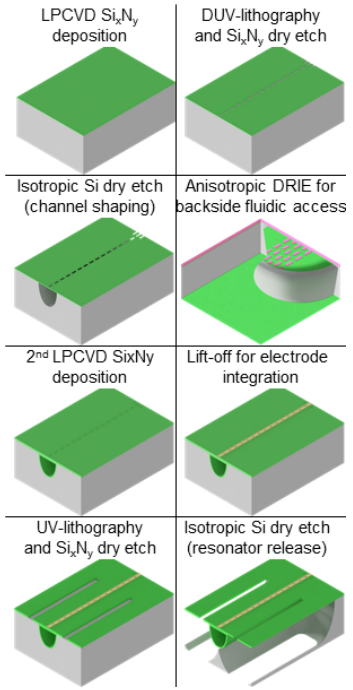

Figure 1. Fabrication principle of MEMS

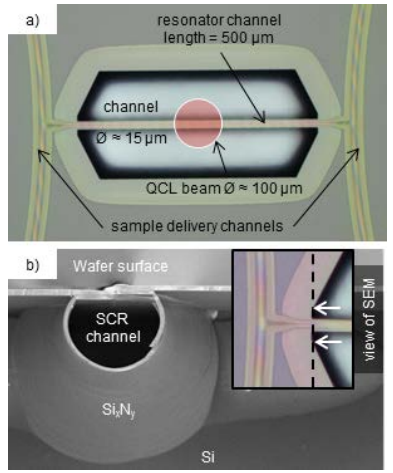

Figure 2.
a) Micrcoscope image of the hollow resonator. Delivery channels on the side connect to backside fluidic access holes. Red circle indicates size of QCL laser beam for IR absorption measurements.
b).SEM of resonator channel cross section. Insert shows plane of cut.

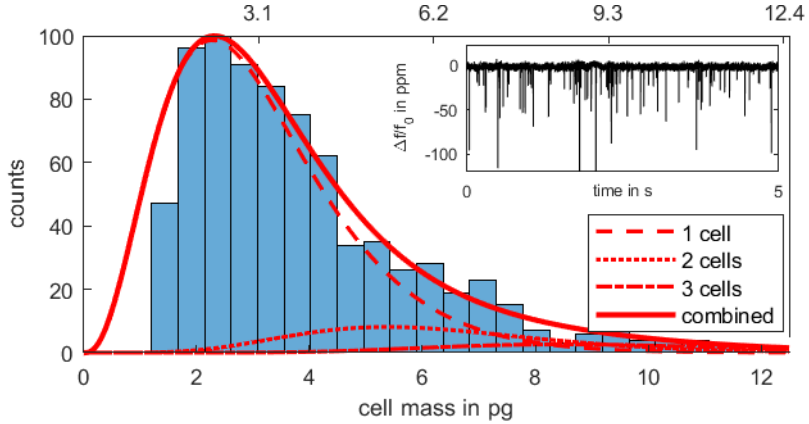

Figure 3. Measurement of a population of n ≈ 800 yeast cells in t ≈ 100s. The histogram is fitted with a combination of delta distributions to avoid negative mass results.